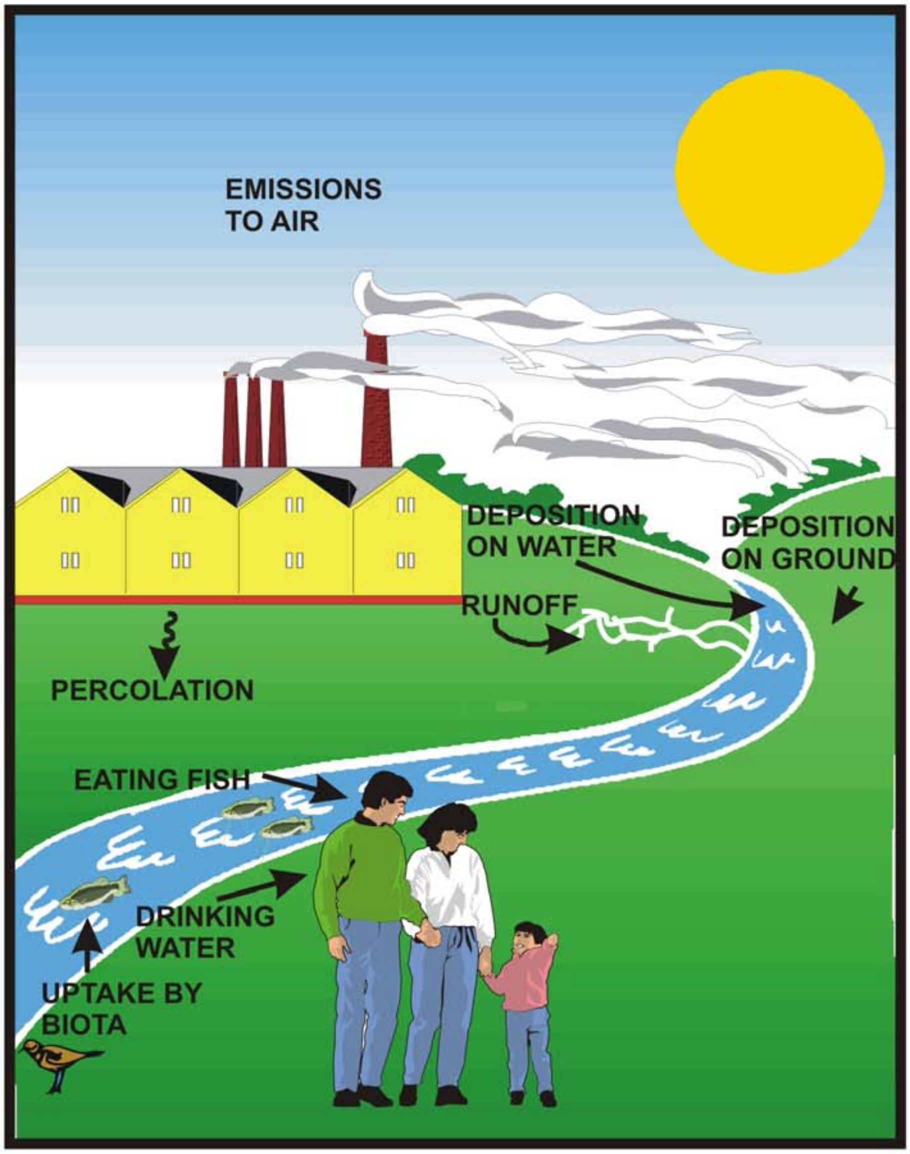
New Jersey Mercury Task Force

Volume II:
Impacts of Mercury in New Jersey



January, 2002

Prepared for New Jersey Department of Environmental Protection

New Jersey Mercury Task Force Report
Volume II
Exposure and Impacts

January, 2002

New Jersey Mercury Task Force

Donald T. DiFrancesco
Acting Governor

Robert C. Shinn, Jr.
Commissioner

State of New Jersey
Christine Todd Whitman
Governor
Department of Environmental Protection
Robert C. Shinn, Jr.
Commissioner

Department of Environmental Protection
Commissioner's Office
401 East State Street, 7th Floor
P.O. Box 402
Trenton, NJ 08625-0402

Dear Reader:

Mercury is a persistent, bioaccumulative, toxic pollutant. An organic form of mercury (methylmercury) has been found at unacceptably high levels in certain fish, and can cause serious health effects in some fish consumers. Other exposure routes are also potentially important, including exposure to primarily inorganic forms of mercury in some private well water.

Through a combination of source reduction and aggressive pollution control measures, we in New Jersey, have achieved some very notable reductions in the environmental releases of mercury over the past decade including reductions in emissions from municipal solid waste and medical waste incinerators.

More significant reductions are feasible and necessary. The Mercury Task Force recommends a strategic goal of an 85% decrease in in-state mercury emissions from 1990 to 2011. (This goal equates to a 65% decrease from today to 2011.) At my request, the Mercury Task Force has diligently assembled a vast body of information to serve as the basis for a comprehensive set of recommendations to reduce the environmental impacts of mercury releases. These recommendations are designed to provide New Jersey with its first comprehensive mercury pollution reduction plan. Implementation of these recommendations will limit mercury exposures to our citizens and our wildlife.

I would like to thank all of the Task Force members for their hard work and dedicated service to the citizens of New Jersey, and I am pleased to accept this comprehensive Mercury Task Force Report. I urge legislators, government officials, the environmental community, business and industry, the scientific and technical community, and all other interested citizens to review this report and determine how they can most effectively work in partnership with the New Jersey Department of Environmental Protection and other state agencies, to achieve these important New Jersey mercury reduction goals.

Sincerely,

Robert C. Shinn, Jr.
Commissioner

E O H S I

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November 2001

Commissioner Robert C. Shinn, Jr.
NJ Department of Environmental Protection
P.O. Box 402
Trenton, NJ 08625-04002

Dear Commissioner:

The members of the Task Force are pleased to submit to you our recommendations for reducing mercury impacts to the environment.

Mercury is a highly toxic material that has no known essential biological properties. It is toxic to adults, but the main health concern today is its potentially profound impact on the developing nervous system and the concern that fetal development can be significantly altered by even low levels of mercury (particularly methylmercury) in the mother's diet. This growing concern, spurred by recent epidemiologic research, has led many governments and other groups to address the problem of mercury in the environment.

Mercury's unique physical properties have led to its use for centuries in a wide variety of commercial applications and industrial processes. Its toxic properties have also been exploited in medicine, dentistry, agriculture, and paint manufacture. Although most uses have been eliminated or reduced (for example, mercury fungicides and batteries), or are being phased out today (for example, mercury thermometers), mercury remains in commerce in a number of forms including dental amalgams, fluorescent lights, thermostats, and certain electric switches.

Today, however, many of the most serious sources of mercury are inadvertent. These include the burning of waste, the use of coal to generate electricity, and the recycling of a variety of mercury-containing products, such as metals. Recognizing that toxic methylmercury occurred at surprisingly high levels in some freshwater fish from many waterbodies in the State, the New Jersey Department of Environmental Protection convened the first Mercury Task force in 1993. This advisory group concluded that emissions from municipal solid waste incinerators were, at that time, the main controllable sources of mercury emissions in the state. Its recommendations and subsequent regulations led to a major reduction in mercury emissions from New Jersey incinerators; the targets set by the first Task Force for this particular industrial sector have been met and surpassed.

It has been my privilege to chair the second Mercury Task Force, convened in 1998 by Commissioner Robert C. Shinn, Jr., which has tackled a much wider array of mercury sources. Triggered, in part, by the concern that energy deregulation would increase the output from midwestern power plants which, as a whole, have relatively high emissions including mercury, the Task Force had to grapple at the outset with recommendations to assure that New Jersey's own energy deregulation law would not exacerbate New Jersey's mercury pollution problem. The Task Force went on to inventory many other sources of mercury to the environment, some of them unanticipated.

Our work has been rendered at times easier, and at times more difficult, by the many reports from federal agencies, other states, non-governmental organizations, and public interest groups that have appeared during the lifetime of the Task Force. New Jersey is by no means alone in considering various approaches, including legislation, to reduce mercury uses and emissions. It has indeed been an exciting time to learn about mercury.

For three years now I have had the opportunity to work with and learn from many dedicated and knowledgeable Task Force members and NJDEP representatives. We have also benefited from the numerous presentations made to the Task Force by outside groups, each with unique knowledge and perspectives. They are identified in Appendix VI.

Work on a voluntary Task Force of this nature is extremely demanding of time and energy. A number of Task Force members and other stable participants were indefatigable in their participation, and I particularly want to thank:

William Baker
Andrew Bellina
Janet Cox
Daniel Cunningham
Robert Dixon
Tom Fote
Betty Jensen
Russ Like
Jerry Marcus
Leslie McGeorge (NJDEP Representative)
Keith Michels
Robert Morris
Joel O'Connor
Valerie Thomas
Robert Tucker

Also, Dolores Phillips played a very active role in the origin and early deliberations of the Task Force.

Many NJDEP representatives contributed to the research and writing of the report. All are listed in Appendix IV.

I particularly thank Bob Morris, Alan Stern and Michael Aucott whose time commitments to the Task Force were great and who each co-chaired one of the two working sub-committees (Impacts and Sources). Leslie McGeorge coordinated all NJDEP technical support for the Task Force, kept the Task Force focused on its charges and integrated its work with other NJDEP projects and programs. Sue Shannon coordinated various aspects of the Task Force and managed the communications and planning of meetings.

Other NJDEP staffers who made major contributions include:

Sunila Agrawal
Alan Bookman
Gary Buchanan
Robert Confer
Jim DeNoble
Mary Downes-Gastrich
Randy England
Joann Held
Mike McLinden
Eileen Murphy
Bill O'Sullivan
Anthony Pilawski
Bruce Ruppel
Michael Winka

I personally thank Commissioner Shinn for the thoughtful organization of the Task Force and his patience in awaiting this report. I trust that it will prove valuable in helping New Jersey and the Nation grapple with an insidious pollutant and reduce its impact on future generations. I echo his charge, that the lessons learned from mercury toxicity, mercury pollution and mercury control, should also help us in reducing human and ecosystem exposure to other environmental hazards which can threaten our growing population.

Sincerely yours,

Michael Gochfeld, MD, PhD
Chair

Charge to the Mercury Task Force
From Administrative Order 1998-08
Signed by Commissioner Shinn in March 1998

The mission of the Task Force is to develop a mercury pollution reduction plan for New Jersey. The Task Force is directed to complete the following tasks:

1. Review the current science on: a) impacts of mercury pollution on public health and ecosystems; and b) mercury deposition, transport, and exposure pathways.

2. Inventory and assess current sources of mercury pollution to the extent feasible, including both in-state and regional sources of mercury pollution.

3. Utilizing available information, quantify mercury pollution's impact on New Jersey's ecosystems, public health, and tourism and recreation industries.

4. Review New Jersey's existing mercury pollution policies.

5. Develop a mercury pollution reduction plan for the State of New Jersey, including:
   A) Recommend mercury emission controls and standards for in-state sources, including: coal fired generators; hazardous waste incinerators; sludge incinerators; hospital waste incinerators; and for other sources deemed necessary by the task force. In recommending controls and standards, the task force will explore renewable energy and alternative fuels to mercury emitting fuels now in use, and review innovative and low cost emission reduction strategies available in various industrial sectors.
   B) Provide timely interim recommendations, as feasible, prior to completion of the task force's overall mission, to the New Jersey Department of Environmental Protection, New Jersey Board of Public Utilities, other state agencies, interstate agencies, and the federal Environmental Protection Agency regarding mercury pollution, mercury pollution controls and standards and the relationship of energy deregulation to mercury pollution.

NJ Mercury Task Force
Final Report

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Volume III
Sources of Mercury to New Jersey's Environment

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Chapter 1 – FORMS OF MERCURY IN THE ENVIRONMENT

A. Introduction

Mercury, a heavy metal, has unique properties. It is liquid at ambient temperature and is approximately 14 times heavier than water. The main mercury ore is cinnabar (mercuric sulfide or HgS), which has been mined at relatively few places on earth. The mines of Idrija (now in Slovenia) operated for more than 500 years until closed in 1995 (Biester et al. 2000). The mercury mines at Almaden, Spain, have operated since 415 B.C. (Hunter 1974). Pliny called it "hydrargyrum" (liquid silver) from which comes the abbreviation on the Periodic Table of the elements, 'Hg'. Its poisonous properties were known to the Romans. The familiar droplets known as "quicksilver" are elemental mercury (Hg^0) and give off mercury vapor. All forms of mercury are toxic to humans and to virtually all other forms of life. Its unique physical properties (heavy liquid) at room temperature have enabled its use for a variety of uses such as in mercury switches, thermostats, thermometers, and other instruments. Its toxic properties (see Volume II Chapter 5) have enabled its use as medications, antiseptics, and pesticides. For these reasons there have been many industrial uses of mercury, leading to health and environmental consequences: occupational exposures of workers; industrial emissions and effluents; and contamination of air, water, soil, and ultimately food chains.

Mercury occurs at very low concentrations in sea water and in soils. There are very few locations on earth where it has been found in concentrations high enough to be mined. Of increasing concern is the fact that mercury occurs in coal. Although mercury is a minor constituent of coal, the reliance on coal as a source of electricity has made it a significant and increasing source of environmental mercury, at the same time that other sources (industrial effluents, incinerator emissions) have declined. Today, the major sources of mercury for the general environment include burning of coal to produce electricity and the incineration of wastes. New Jersey's first Mercury Task Force addressed the latter source and its success is evident by the tremendous reduction already achieved in mercury emissions from waste incinerators.

The first of these sources, coal-fired power plants, remains an important source of mercury and other toxic air pollutants, particularly in the face of increasing demands for electricity imposed by growing populations and increased industrialization. The deregulation of electric power in the United States and in New Jersey may exacerbate the problem since older and cheaper plants will be able to increase their market share of electricity by accessing markets formerly closed. At the same time, a failure to develop renewable energy sources or achieve energy conservation may mean that mercury pollution from coal-fired power plants will increase.

The Task Force has identified many other sources of mercury, most of which can be readily controlled, and some of which can be eliminated. The Task Force has obtained data that allows quantitative estimates of the releases from each source (see Volume III).

Organizing the information on mercury in a coherent manner was challenging. Chapters 1-6 of this volume provide information on mercury in general, while chapters 7-11 focus on mercury in NJ. Although Task Force members and DEP staff found abundant information on mercury, there remain many gaps in knowledge.

B. Organic Mercury

The forms or species of mercury are usually classified into the broad categories of organic and inorganic. They have different physical, chemical and toxicological properties. There are several forms of organic mercury, including phenylmercuric acetate, dimethylmercury and monomethyl mercury (ATSDR 1999a). Monomethylmercury, usually referred to simply as methylmercury (MeHg), is the most widespread organic form in the environment and is the toxic form of greatest concern to the environment. It has been demonstrated that in aquatic systems anaerobic bacteria can convert inorganic mercury to organic mercury forms (WHO 1990). Both dimethylmercury and monomethyl mercury is formed in aquatic systems; however, dimethylmercury is highly volatile and is rapidly and essentially completely released through the water column to the atmosphere, particularly in fresh waters. Methylmercury compounds also occur, usually at trace concentrations. MeHg is, in fact, an ion (CH_3 -Hg^+), which is found in association with various anions (negatively charged ions) such as sulfate, chloride and hydroxide. In organisms, MeHg is bound mainly to sulfur in amino acids, protein, glutathione and related compounds (NRC 2000). Exposure of humans to MeHg is almost exclusively through consumption of fish (ATSDR 1999a). Mammals and birds may be exposed to MeHg through consumption of fish, consumption of other fish-eating species, or through consumption of lower order biota, such as insects and plankton, which also incorporate MeHg, albeit at lower concentrations (USEPA 1997d).

Methylmercury poisoning of humans was first recognized at Minamata, Japan around 1960. Hundreds of fishermen and their families were severely poisoned during the 1950's by methylmercury that bioaccumulated in fish due to release of mercury to the bay from a local chemical plant. A similar episode occurred in the 1960's in Niagata, Japan. Epidemics of organic mercury poisoning from consumption of grain treated with organomercurial fungicides have also occurred in Iraq and Guatemala. A family in New Mexico was poisoned by eating pork from their pigs which they had fed on fungicide-treated grain.

C. Inorganic Mercury

The inorganic forms of mercury include elemental mercury (Hg^0) which is unique among metals in being liquid at ambient temperature and being quite volatile. It exists in equilibrium between the liquid and vapor forms. There are two ionic forms of mercury, mercuric Hg^{++} and mercurous Hg^+. The mercuric form is more environmentally stable, and therefore predominates. Hg^{++} is commonly found as mercuric chloride ($HgCl_2$), and mercuric sulfide (HgS). Cinnabar, the most common mercury ore, contains HgS. $HgCl_2$ is soluble in water (1 g/35ml) (ATSDR 1999a) and is a relatively common form of inorganic mercury in aquatic systems, the atmosphere, and in aerobic soils. HgS is the most stable of the common inorganic species and is essentially insoluble in water (ATSDR 1999a). It thus tends to function as a long-term sink for environmental mercury in soils and sediments. Mercury has a high affinity for sulfur, and under a variety of conditions it will bind strongly to either inorganic or organic sulfur. Since proteins (including all enzymes) contain sulfur, and the cross linkages between sulfur confers important structural and functional properties, mercury has the capability of interfering with a great many biochemical reactions by disrupting these disulfide bonds. Other forms of Hg^{++}, such as mercuric sulfate ($HgSO_4$) and mercuric oxide (HgO), are potentially important in atmospheric processes, but they tend to be short-lived in the environment (Mason et al. 1994). Those forms of Hg^{++} that are moderately soluble (e.g. $HgCl_2$) can contaminate surface and groundwater and are largely responsible for the elevated levels of mercury in private wells in areas of southern New Jersey.

Exposure to elemental mercury occurs in certain workplaces, in health care facilities, and occasionally in homes. The droplets of mercury are attractive, and children have been known to bring mercury home to play with. The cultural practice of Santeria also results in household exposures to elemental mercury. Breakage of thermometers and spills from gas meters during their removal are infrequent, but important sources of mercury. When such spills occur it is important that they be cleaned up quickly. Information on how to do this is available at the NJDHSS web site address http://www.state.nj.us/health/eoh/survweb/merchome.pdf.

Liquid droplets will give off toxic mercury vapor which can be inhaled by the occupants. Globules of Hg^0 may persist for a long time before they evaporate completely. However, they may be more stable under anaerobic conditions under water or in the soil where they can become coated with a stable layer of insoluble HgS. Unless these globules are transferred to an oxidizing environment (due to dredging of sediment for example), such deposits of coated Hg^0 can remain inert for a long time. This may be important in moderating the migration of Hg^0 in landfills, for example.

Hg^0 vapor in the atmosphere is subject to long range transport. Hg^0 is slightly soluble in water (0.08 mg/l at 25°C) (ATSDR 1999a) and a small fraction of Hg^0 vapor can, therefore, be washed out of the atmosphere during precipitation events. The more likely fate of Hg^0 however, is eventual oxidation to Hg^{++} by reaction with atmospheric oxidants such as oxygen, ozone, and chlorine (Mason et al. 1994). Once converted to the Hg^{++} form, the mercury is much more soluble and more subject to washout of the atmosphere with precipitation. This is called “wet deposition” and is a major source of mercury input to the environment. A small amount of the mercury may adhere to fine particles in the atmosphere and may fall out without rainfall as “dry deposition”. Dry deposition also includes gaseous mercury and mercury compounds that are directly absorbed by plant foliage, soils and other media. The relative contribution of wet and dry deposition is variable and not well quantified.